

# Seismic Imaging as a Means to Investigate Abandoned Underground Mines

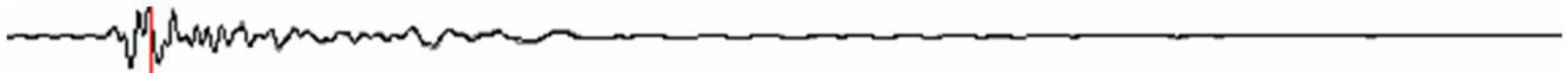
Interstate Technical Group on Abandoned Underground Mines

April 23, 2004

Dick Ryan

Kansas DOT

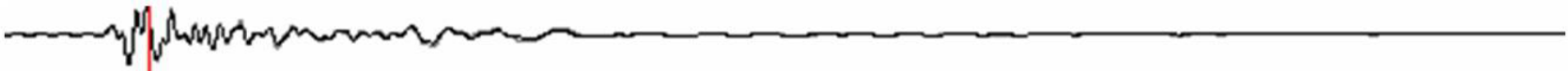
***NSA Geotechnical Services, Inc.***



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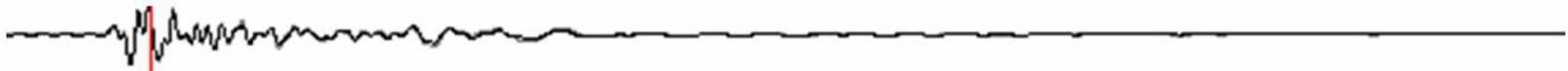
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# Are Old Mine Works Causing Surface Subsidence?

- 1,800 m of US Highway 69 in SE Kansas overlies abandoned, underground lead and zinc mines
  - Mines were active in first half of 20th century
  - Available mine maps may not be accurate
- Several surface subsidence incidents near highway since 1940s
  - Believed related to abandoned mine openings
- Goal is to understand effect, if any, of mine openings to reduce the risk of catastrophic subsidence

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**Kansas Department  
Of Transportation**

Photograph No. 10

Title: *North Boundary of Current Project - View to South*





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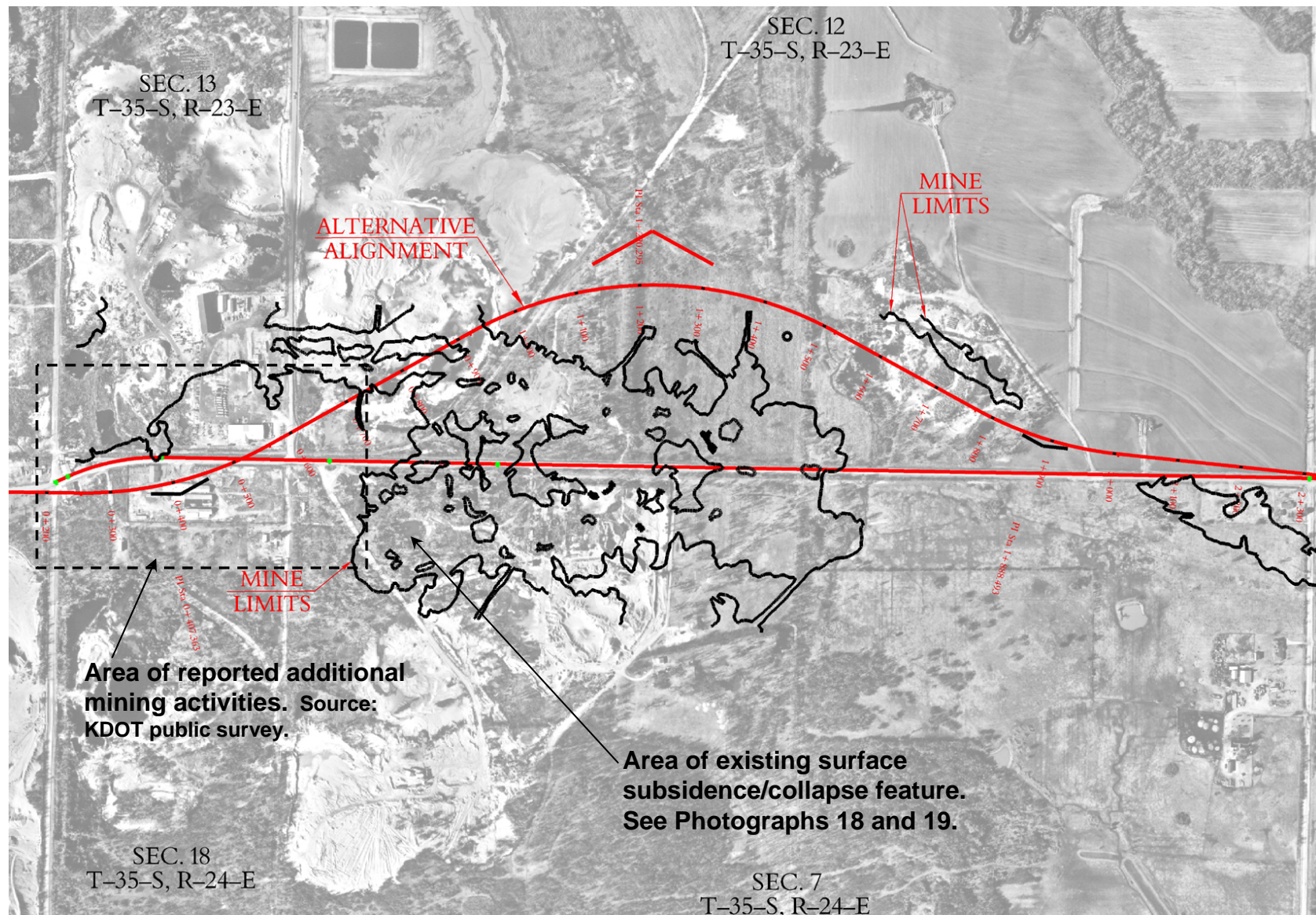
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Photograph No. 19

Title: *Subsidence: Approx. 300 Feet East of US-69 at  
Kansas-Oklahoma Border*





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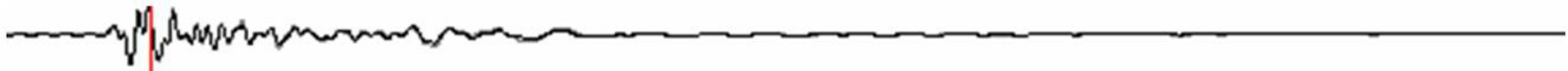
**Photograph No. 20**

**Title:** *Alternate Alignment*

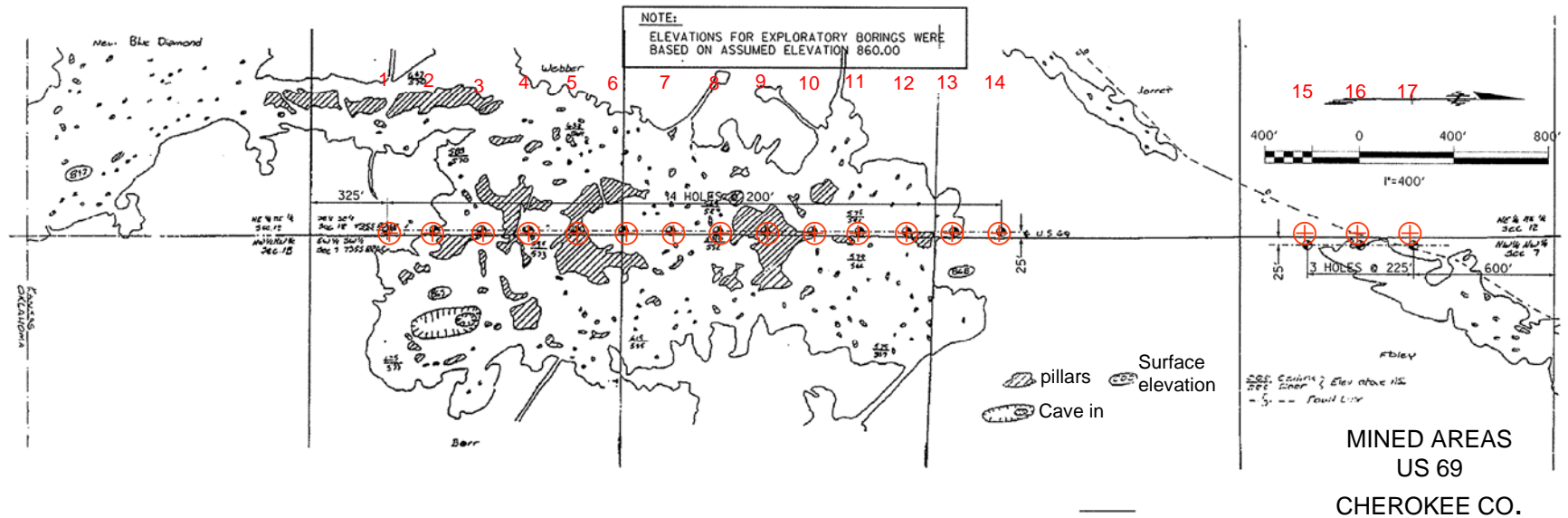
# Using Seismic Tomography

- Use RockVision3D™ to image two vertical profiles of the ground under US Highway 69
  - Borehole spacing varied from 40m to 70m
- Purpose
  - Identify unmapped mine openings
  - Indicate the existence and severity of any migrating caving zones above the old mine openings

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# Position of Boreholes Relative to Mapped Mine Workings

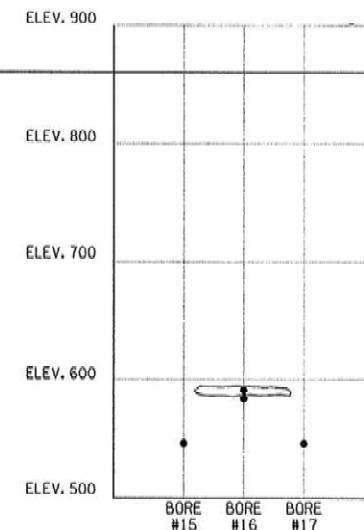
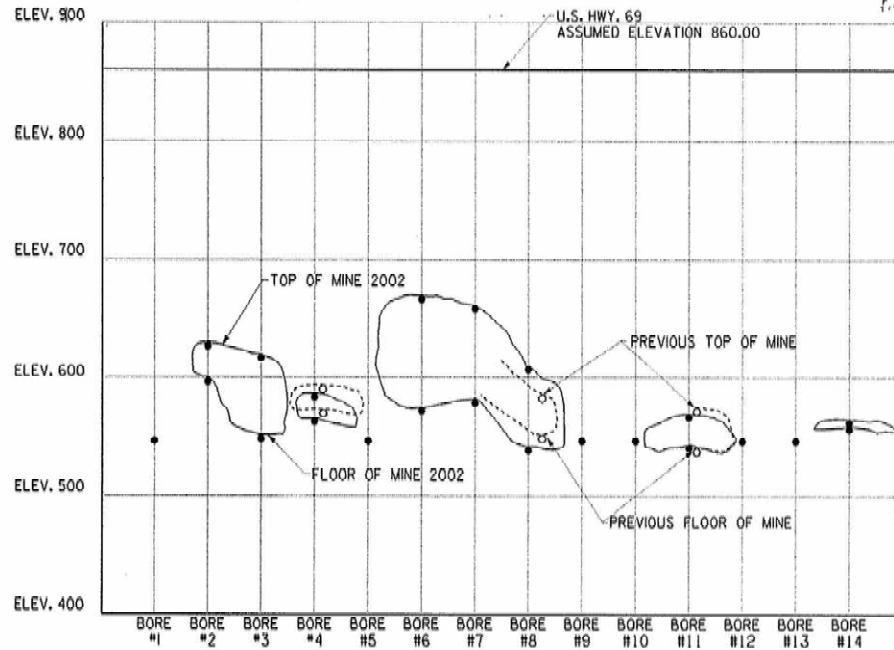


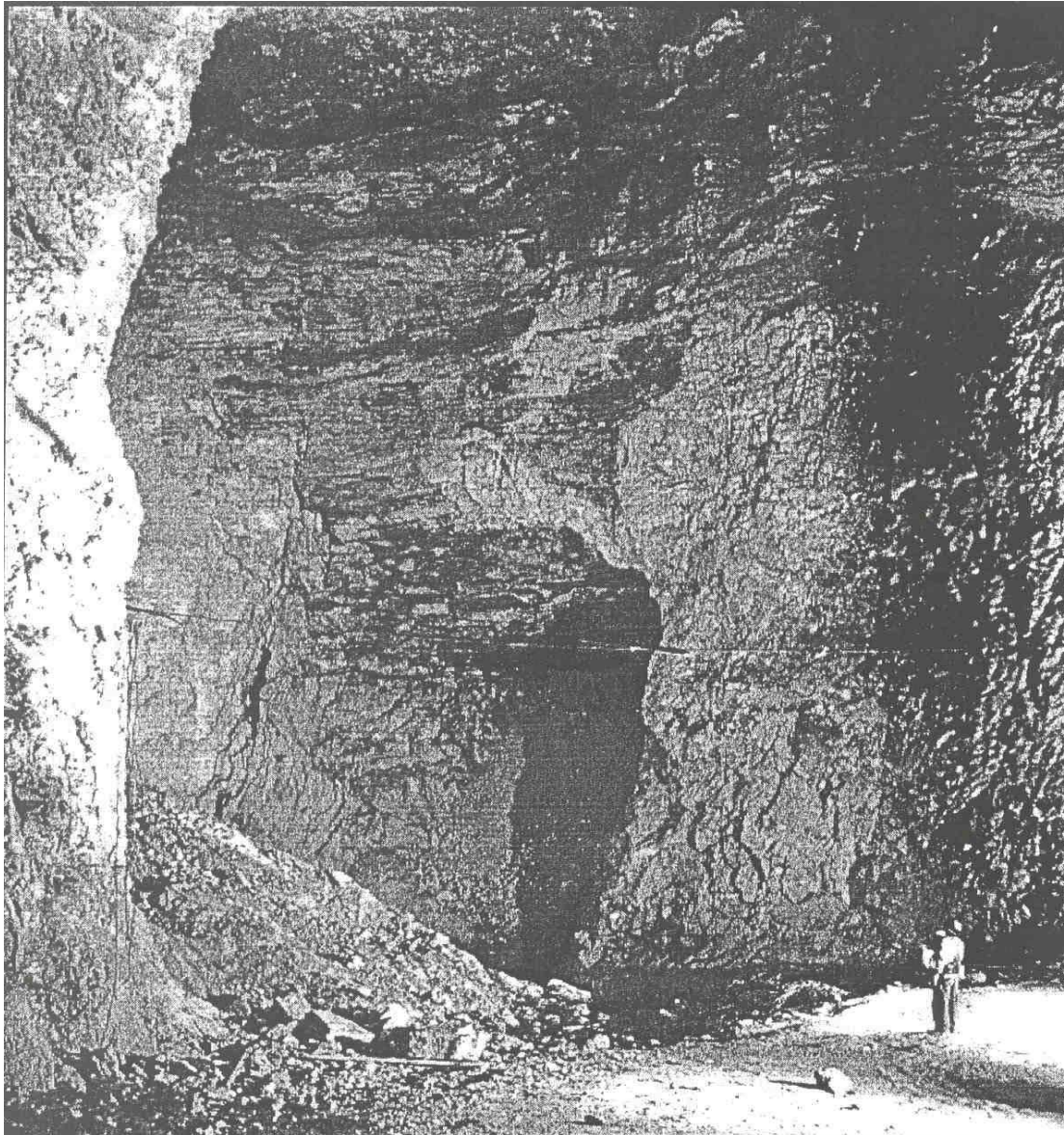


# Vertical Profile of Voids Encountered During Drilling

**LEGEND**

- BORE DEPTH LOCATION
- NEW DEPTH CONTOUR
- EXIST. BORE LOCATION
- - - EXIST. DEPTH CONTOUR





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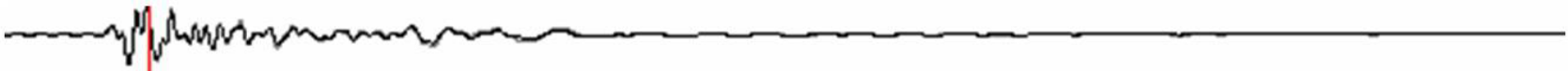
Photograph No. 9

Title: *Mine Cavern Believed Similar to NSA Panels 5 & 6*

# RockVision3D™

- RockVision3D generates ground velocity images based on measurement of the time it takes seismic energy to travel between known locations.
- Basic principle
  - Seismic energy travels through different material types with different attenuation rates and velocities.
  - Seismic waves will travel faster through competent or highly stressed material and will be generally less attenuated than through broken/fractured ground or voids.

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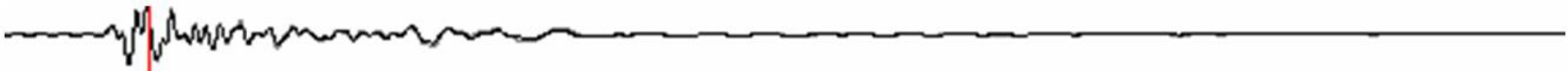




# Equipment Used

- Array of source and receivers was utilized in 17 drill holes
  - 2 hydrophone strings were used
  - Downhole air gun as seismic source
    - Discharged at 2-meter intervals in the source holes
  - Data Collection: 24-channel seismograph
    - Signal initiation triggered recording of seismic waves

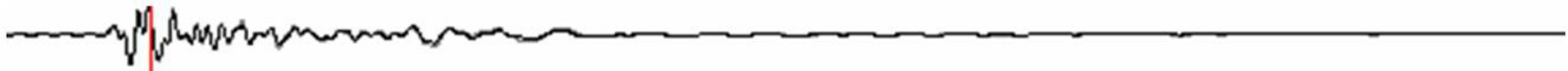
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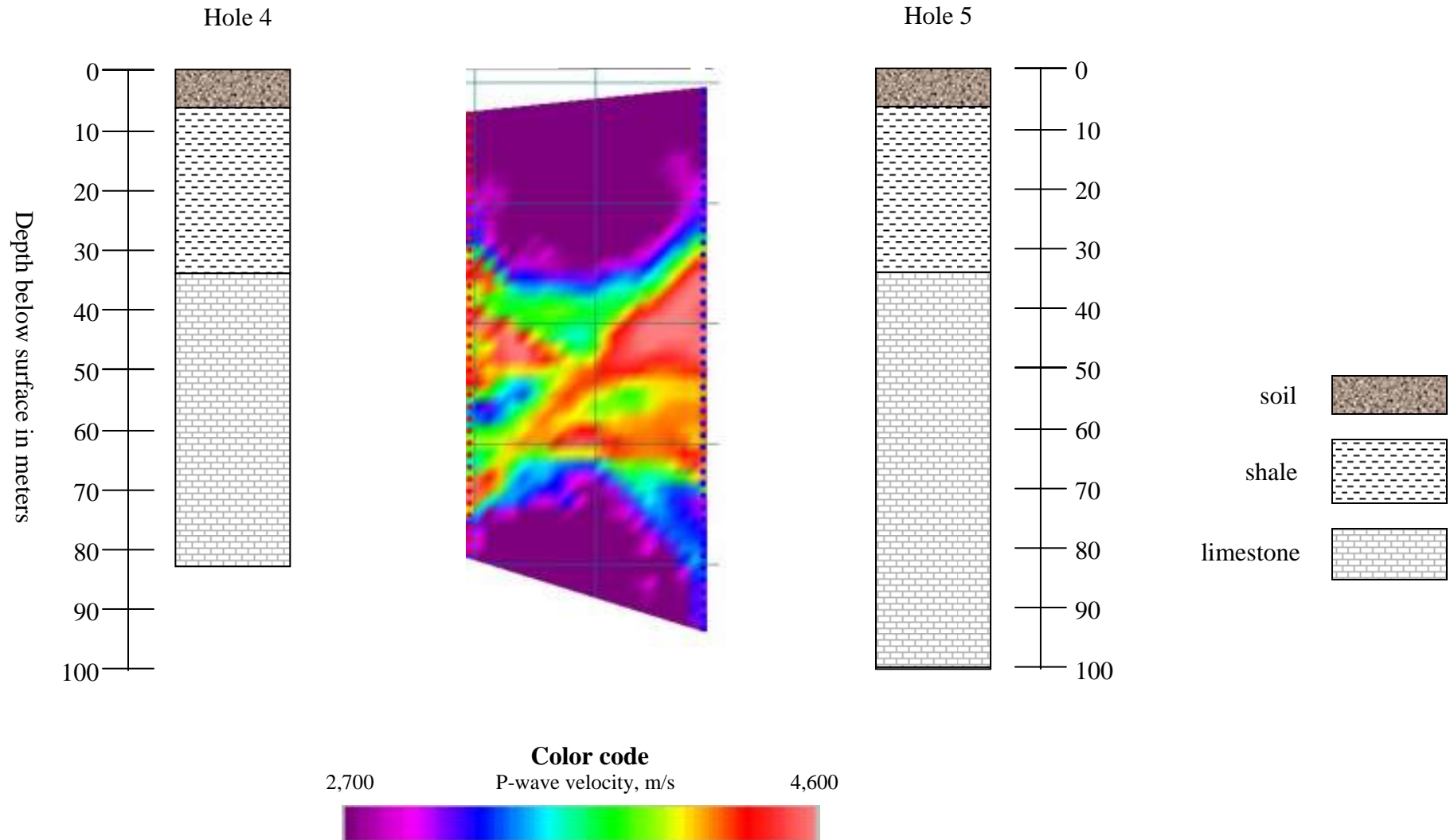
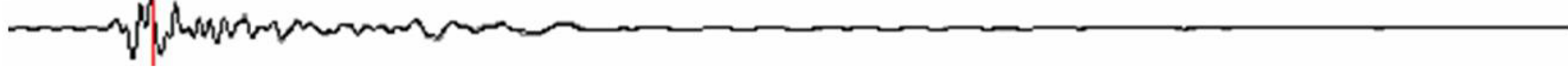
# Interpreting the Images

- Areas of the tomograms shown in purple or blue indicate voids or zones of weakness
  - Regardless of their origin (natural or mining-related), their potential impact should be evaluated

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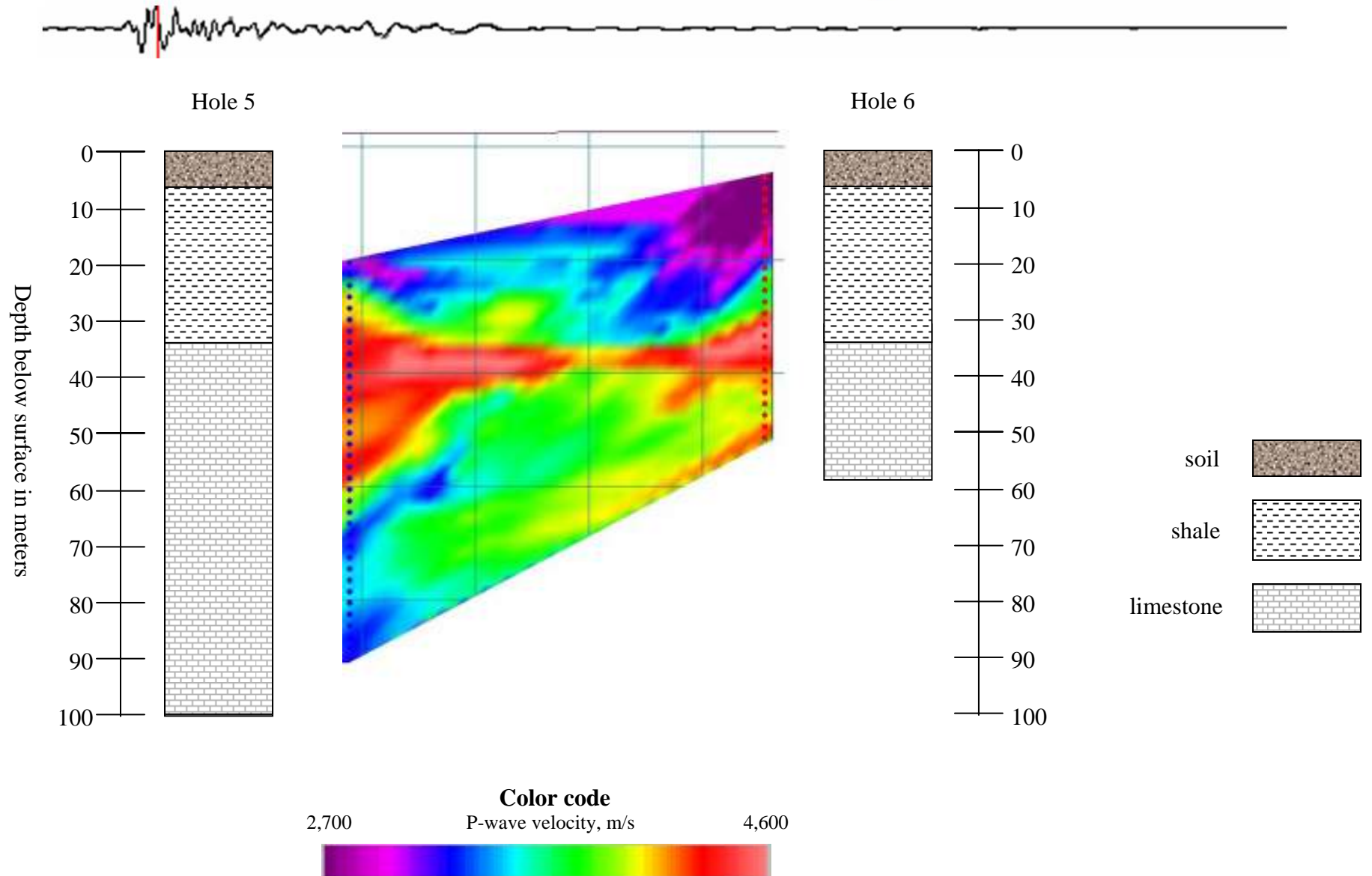
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**Approximately 25 m of competent limestone beneath the shale is indicated, but a large void, likely caused by mine roof failure migrating toward the surface is present.**

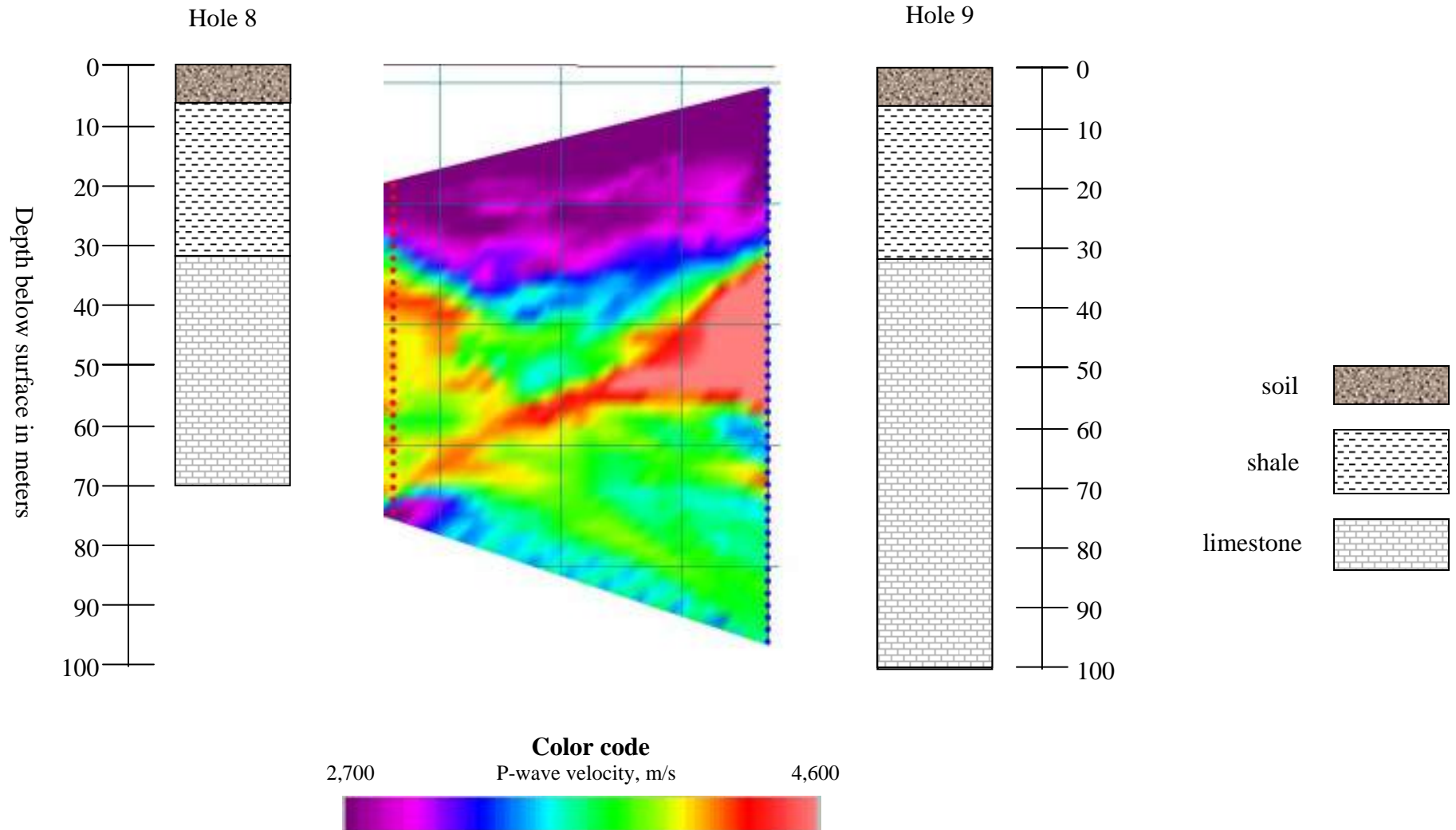
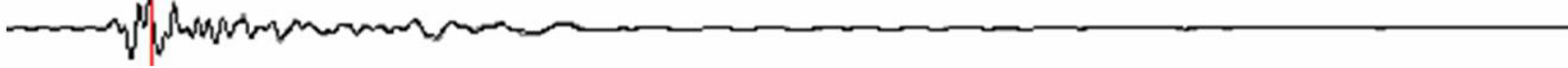


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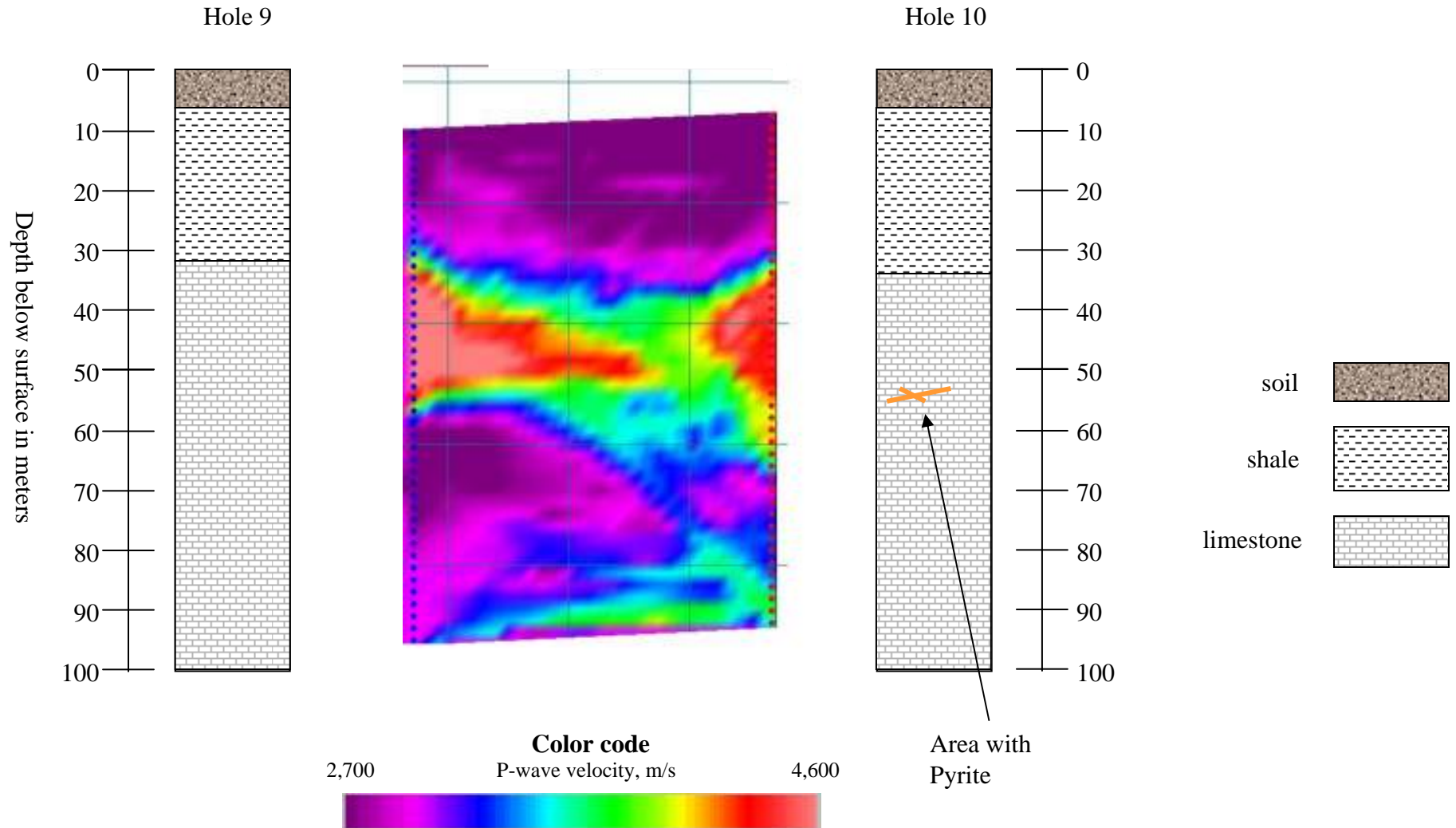
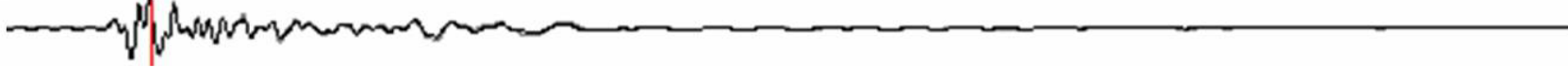
The tomogram shows that only a thin (~5 m) layer of competent limestone exists between the mine roof and the shale. The remaining limestone appears to be less competent. There is no indication that roof failure has migrated up through this weaker limestone layer, but the potential for roof failure migration is likely higher in this area because of the reduced limestone competence.

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Competent limestone is evident (~30 m near Boring #8 and ~70 m near Boring #9), although velocities in the limestone are markedly lower than in previous panels. This is probably due to numerous small voids or brecciation within the limestone, rather than to roof failure migration.

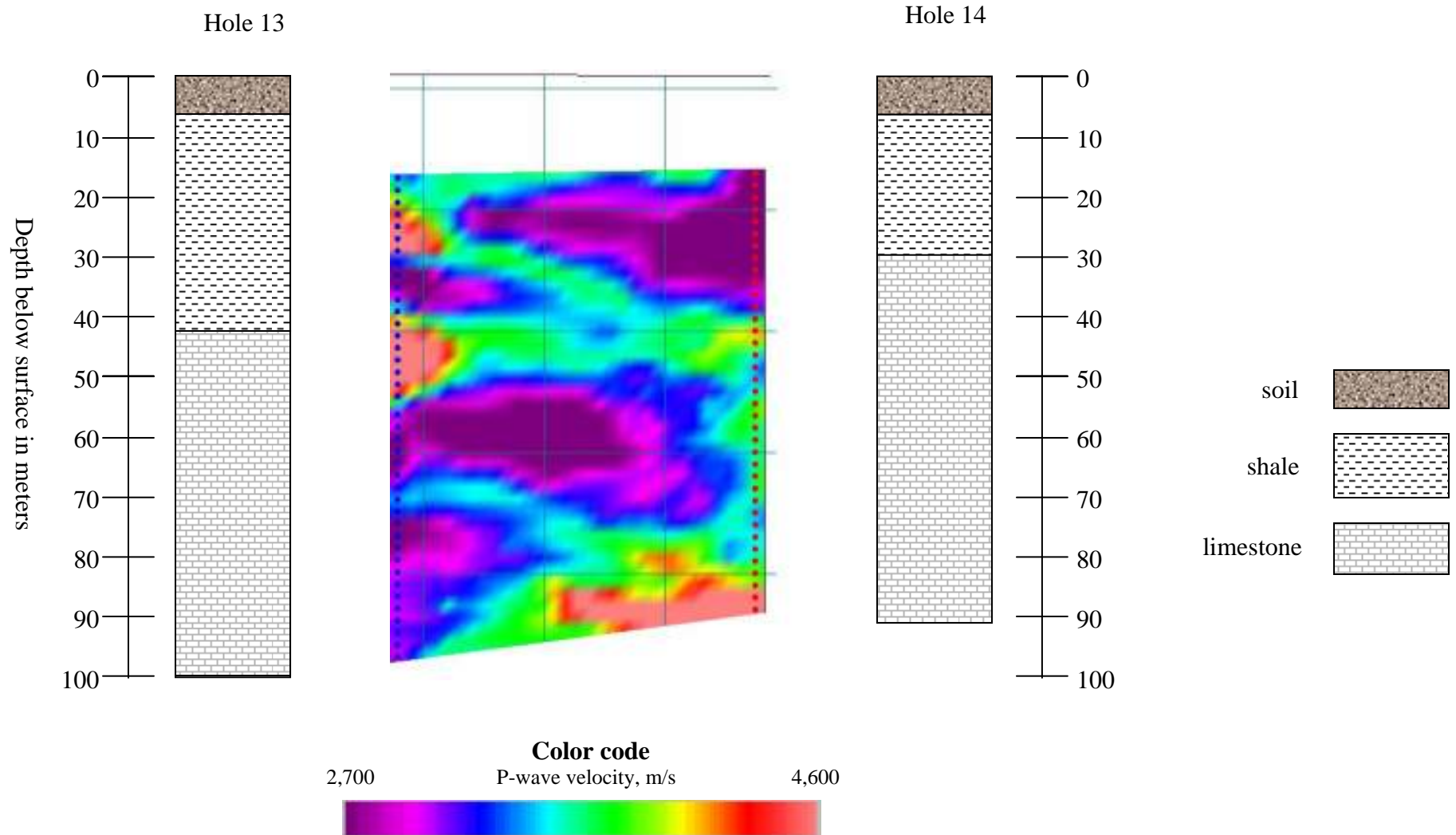
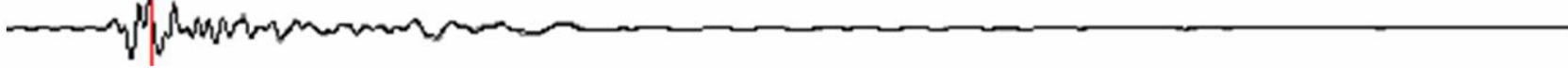
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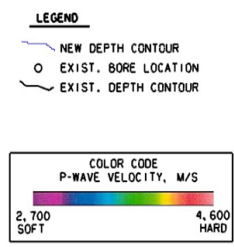
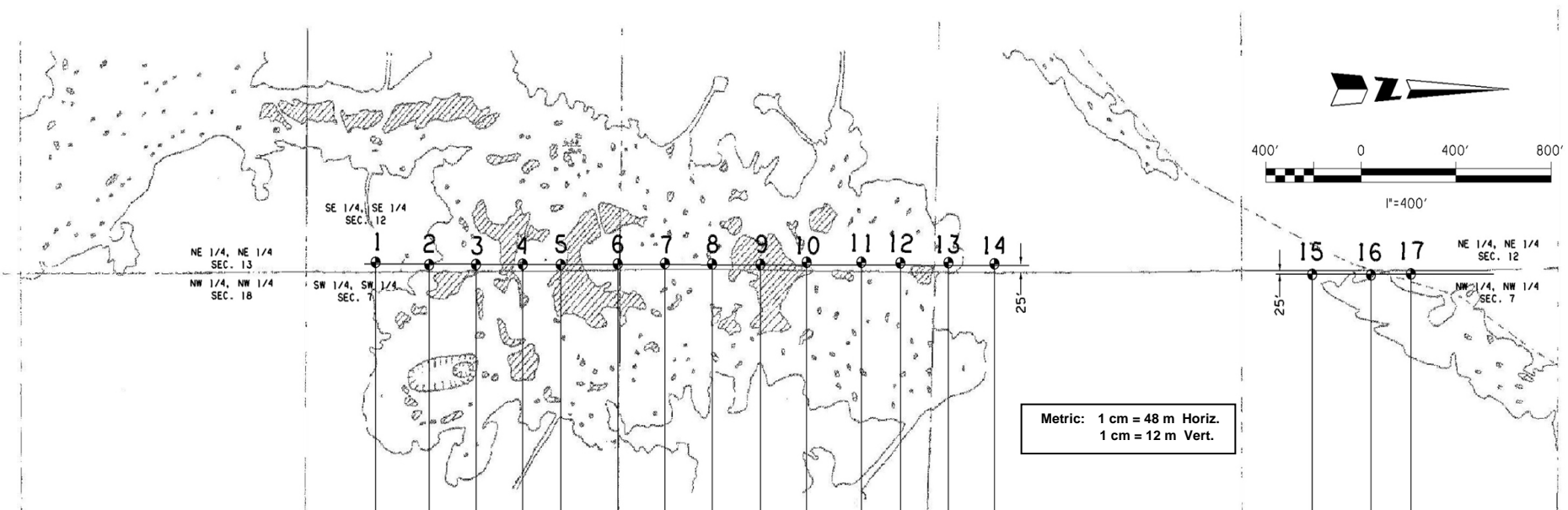
**Tomogram indicates a large void between Boring #9 and Boring #10, closer to Boring #9. The drill log indicated water in this area, but no indication of a mine void. This could possibly be a breccia zone. About 20 m of competent limestone separates the void and the shale.**



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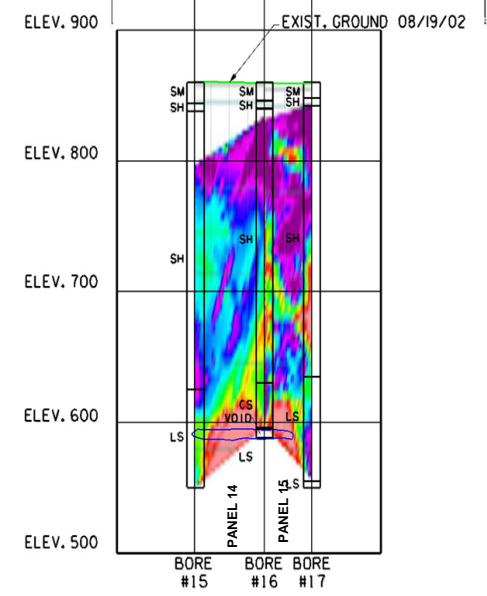
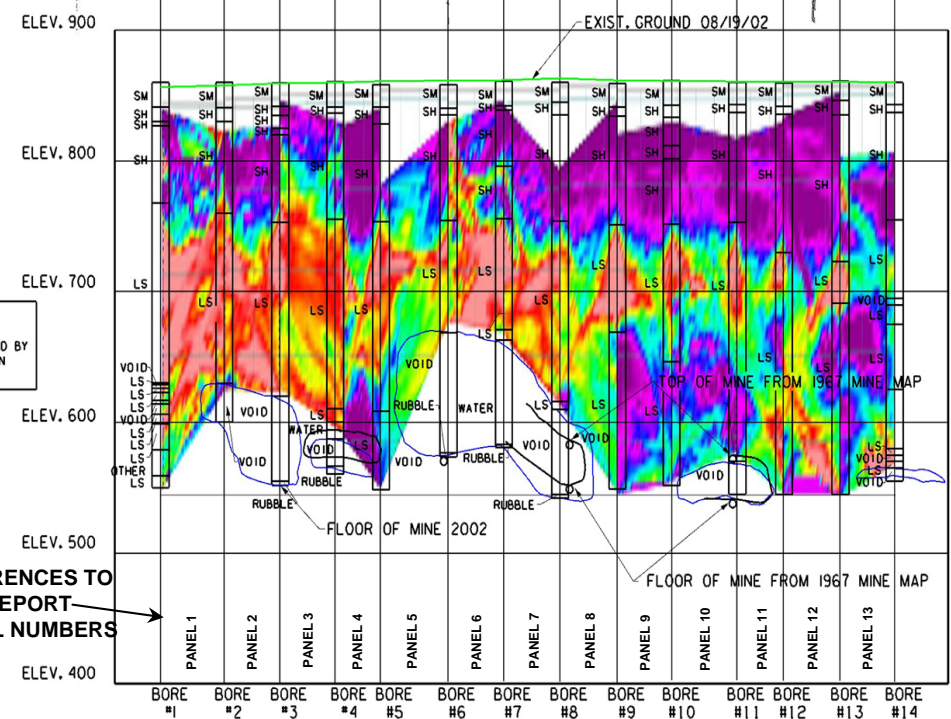


**Apparent voids exist between Borings #13 and #14, closer to Boring #13.  
Because of their location, it is surmised that these voids are naturally-occurring rather than mining-related.**



NOTE:  
BORING LOGS OF DOWN HOLE VIBRATORY  
HAMMER DRILLING PREPARED & PROVIDED BY  
KANSAS DEPARTMENT OF TRANSPORTATION  
GEOLOGY STAFF.

REFERENCES TO  
NSA REPORT  
PANEL NUMBERS



REVISION  $\Delta$  03-07-03  
REVISION:  $\Delta$  10-24-02, UPDATED BORING INFORMATION.

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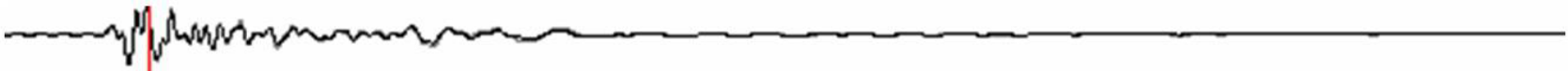
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15000 West Sixth Avenue, Suite 100  
Golden, CO 80401

**FIGURE 1**  
TOMOGRAPHIC MAPPING  
OF EAGLE PITCHER MINES  
BORING LAYOUT PLAN  
SHEET 1 OF 1

# Conclusions

- To summarize the tomography results:
  - Only Panel 4-5 clearly indicated a void that appears to be related to failure of the mine roof
  - Panel 9-10 shows the existence of voids that may be mining-related, but are more likely naturally occurring
  - Limestone of varying degrees of competence exists throughout the Panels
    - Usually of significant thickness (20m to 50m)

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# In Summary

- Abandoned mine works can have impact on surface infrastructure.
- There is a benefit in knowing the extent and geometry of abandoned mine works.
- Seismic imaging can provide accurate description of subsurface ground conditions.
- Having accurate data can greatly reduce costs and risks associated with potential surface impacts of old mine workings.
- For more details visit <http://www.nsageotech.com>

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